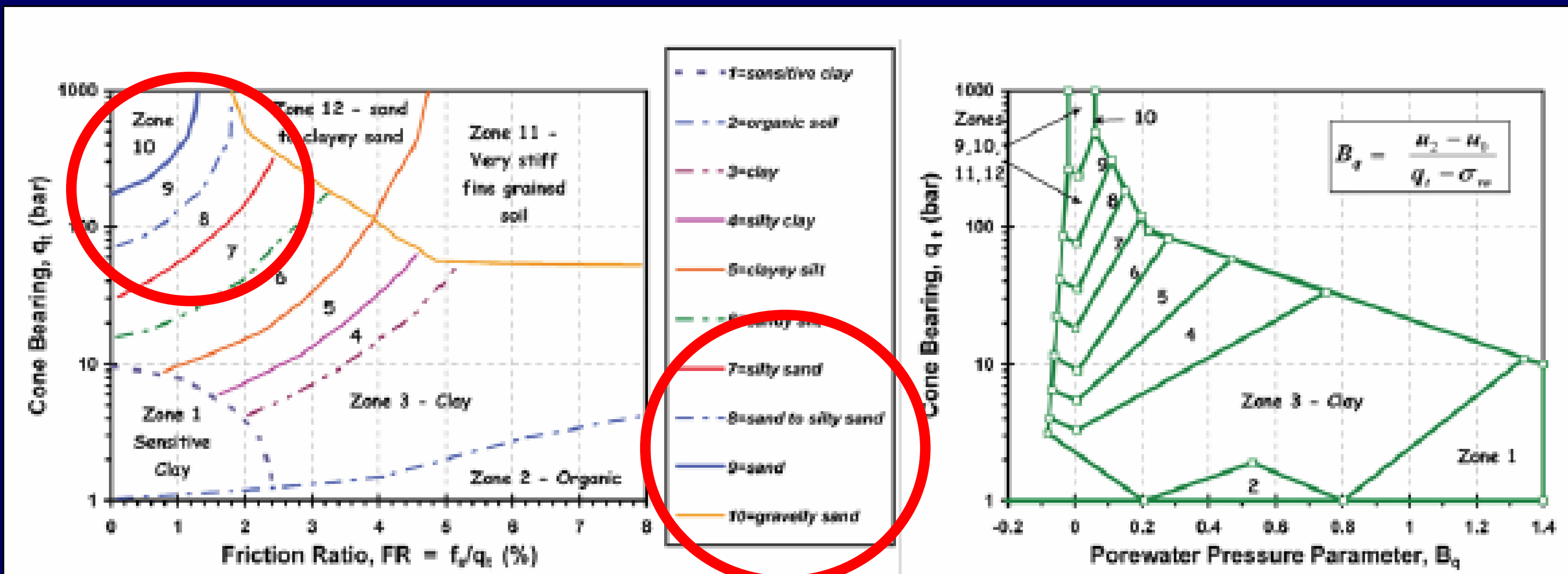
Liquefaction analysis with CPT data

Application of CPT data to seismic hazard analysis

1. Determination of soil stratigraphy and identification of potentially liquefiable soils
2. Measurement or calculation of shear wave velocities for use in ground-shaking analyses
3. Assess soil liquefaction potential using deterministic and probabilistic procedures

1. Identify the presence of liquefaction prone soils

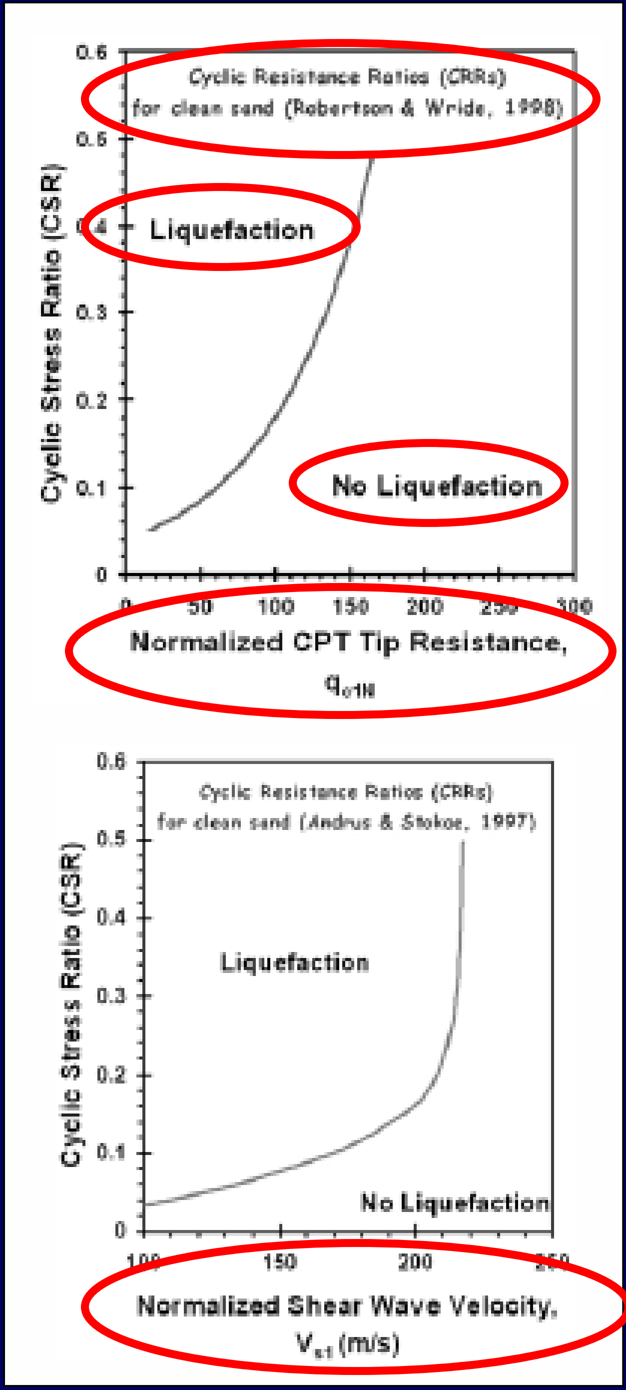


2. The small strain stiffness (G_0 or G_{max}) determined from the shear wave velocity is a required input parameter for analyses that are used to estimate the intensity of ground shaking.

3. Using conventional methods, the intensity of ground shaking from seismic loading is expressed as the Cyclic Stress Ratio (Seed and Idriss, 1971)

$$CSR = \frac{\tau_{ave}}{\sigma'_{vo}} = 0.65\left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right) r_d$$

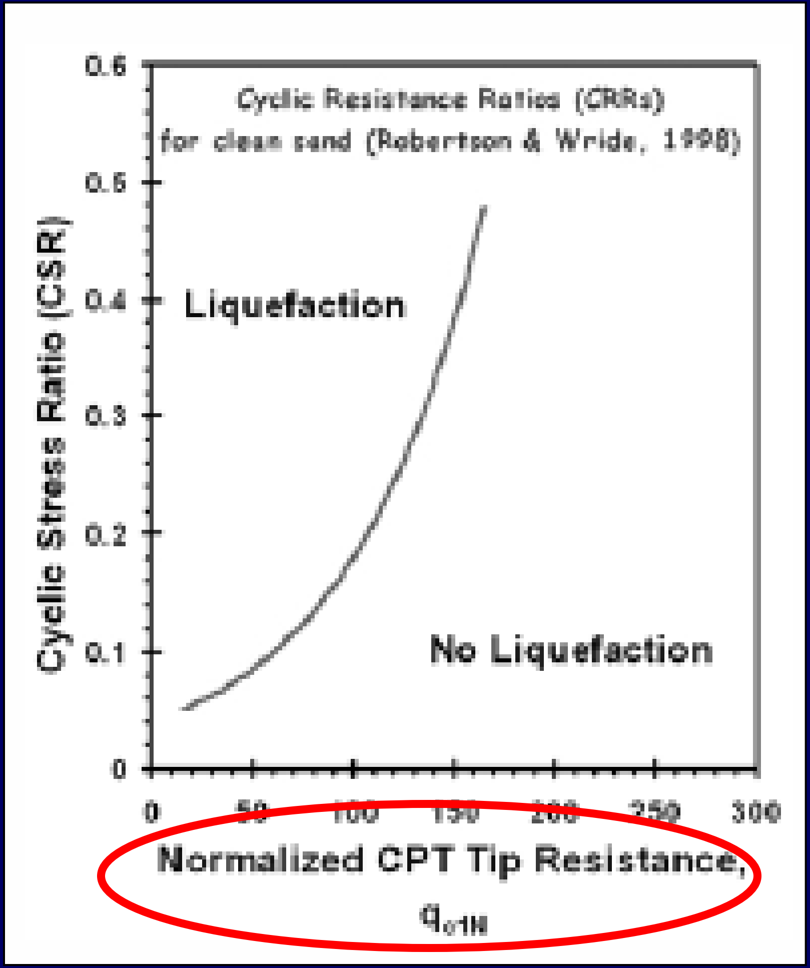
- τ_{ave} = average equivalent uniform shear stress, 65% of the maximum induced stress
- σ'_{v0} = effective vertical stress
- a_{max} = peak ground acceleration
- g = gravitational acceleration constant
- σ_{v0} = total vertical stress
- r_d = stress reduction coefficient



The threshold resistance of soil to liquefaction is expressed as the Cyclic Resistance Ratio (Seed and Idriss, 1971)

The CRR may be determined from either stress-normalized cone tip resistance data or stress-normalized shear wave velocity data.

Calculate the stress-normalized tip resistance to evaluate the deterministic liquefaction potential of clean sand



- $q_{c1N} = q_t/(\sigma_{vo}' - \sigma_{atm})^{0.5}$
- where:
  - q_t is the total cone tip resistance (q_c corrected for pore pressure effects)
  - σ_{vo}' is the effective overburden stress
  - σ_{atm} is atmospheric pressure (100 kPa = 1.0 TSF)

For silty sand, calculate the adjusted stress-normalized tip resistance using an iterative process

$(q_{c1N})_{cs} = K_c\ (q_{c1N})$

- K_c is the correction factor for apparent fines content

First, compute the soil classification index I_c

$I_c = ((3.47 – \log Q)^2 + (1.22 + \log F)^2)^{0.5}$

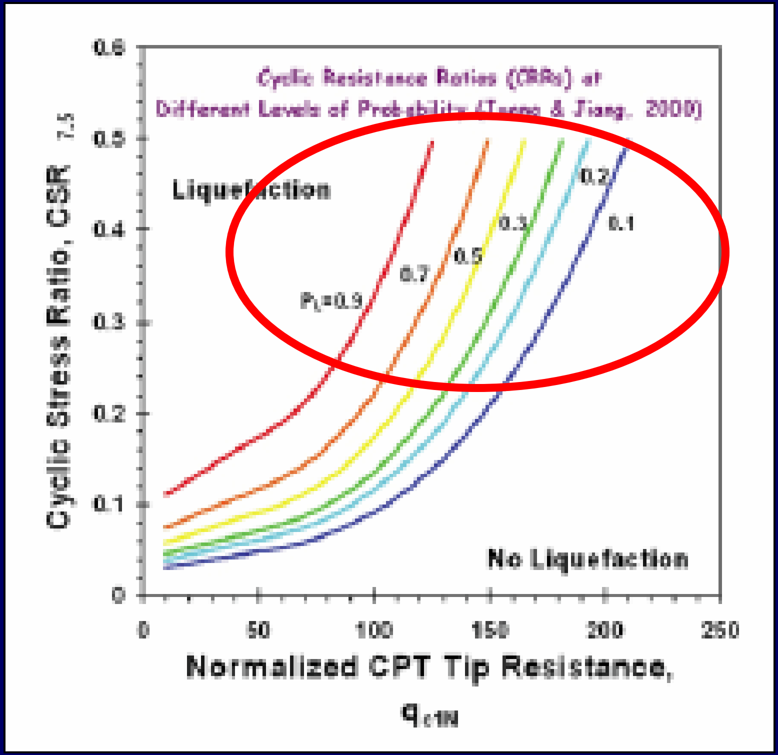
- $Q = (q_t – \sigma_{vo})/\sigma_{v0}'$
- $F = (f_s/((q_t – \sigma_{vo}))\ (100)$

If I_c <= 1.64, $K_c = 1.0$

If $I_c > 1.64$, $K_c = -0.403(I_c^4) + 5.581(I_c^3) - 21.63(I_c^2) + 33.75(I_c) - 17.88$

Calculate $(q_{c1N})_{cs}$ and substitute this value for q_t used in the Q and F calculations in the box above. Recalculate I_c, K_c and $(q_{c1N})_{cs}$ until convergence on $(q_{c1N})_{cs}$ is achieved.

The safety factor (F_s = CRR/CSR) can be determined from CRR curves based on the definition of the Probability of Liquefaction, P_L (Juang and Jiang, 2000)



$$P_L = 1/(1 + (F_s)^{3.34})$$

P_L	F_s
0.69	0.80
0.59	0.90
0.50	1.00
0.42	1.10
0.35	1.20

Additional methods to obtain probabilistic assessments of liquefaction potential are available from authors such as Moss (2003, 2006).

Questions?